Annular microelectromechanical angular rate sensor

The present invention relates to annular microelectromechanical angular rate sensors.

Annular microelectromechanical angular rate sensors operate according to the principle that a self-contained structure, which is typically designed as a circle or ring, is made to oscillate above a substrate parallel to the substrate plane. If the ring is rotated about an axis of rotation perpendicular to the substrate plane, the oscillation movement of the ring generates a Coriolis force on the individual mass points of the ring. This leads to the superimposition of a further oscillation, the amplitude of which depends on the angular rate of the rotation. As the oscillation direction of this detection oscillation is, in principle, predetermined by the position of the ring and the excitation oscillation, and the parameters of the excitation oscillation are also known, the detection oscillation can be read out in order to determine the angular rate.

In practice, plate electrodes placed along the circumference of the ring are often used to excite and read out the oscillations. However, this takes up a lot of space and does not meet all requirements for the angular rate sensor. Such plate electrodes can also be used to compensate for so-called quadrature errors, which often affect microelectromechanical sensors due to inevitably arising manufacturing tolerances.

However, the problem here is that electrode plates placed on the outside along the circumference of the ring are limited in terms of the electrode area. As a larger signal can be fed in or read out via a larger electrode area, the use of external electrode plates is disadvantageous. It is also not always possible to design the excitation and readout electrodes optimally with external electrode plates.

Embodiments of the present invention disclose an annular microelectromechanical angular rate sensors with a large electrode area, which have a compact design and allow compensation for quadrature errors without restricting the possibility of exciting the ring of the angular rate sensor or reading out oscillations.

According to a first aspect of the present invention, there is provided a microelectromechanical angular rate sensor, including: anchor structures via which the angular rate sensor is connected to an external substrate; a flexible ring structure which forms a circle at rest and which is suitable for producing an excitation oscillation substantially parallel to the plane of the circle above a substrate, said excitation oscillation being superimposed with a detection oscillation generated by the Coriolis force during a rotation of the ring structure; at least one coupling structure which is connected to the ring structure and is designed in such a way that it is, together with electrodes which are fixed to the substrate, suitable for compensating for a quadrature error of the angular rate sensor; and first spring elements each comprising only two ends, which act on the ring structure at their first ends and are connected to the substrate at their second ends via anchor structures; wherein in each first spring element the first end is located opposite to the second end with respect to a center of the respective first spring element in a direction of main extension of the respective first spring element; and the at least one coupling structure and the first spring elements act on the same side of the ring structure.

According to a second aspect of the present invention, there is provided a microelectromechanical angular rate sensor, including: a flexible ring structure which forms a circle at rest and which is suitable for producing an excitation oscillation

Claims

1. A microelectromechanical angular rate sensor, comprising:

anchor structures via which the angular rate sensor is connected to an external substrate;

a flexible ring structure which forms a circle at rest and which is suitable for producing an excitation oscillation substantially parallel to the plane of the circle above a substrate, said excitation oscillation being superimposed with a detection oscillation generated by the Coriolis force during a rotation of the ring structure;

at least one coupling structure which is connected to the ring structure and is designed in such a way that it is, together with electrodes which are fixed to the substrate, suitable for compensating for a quadrature error of the angular rate sensor; and

first spring elements each comprising only two ends, which act on the ring structure at their first ends and are connected to the substrate at their second ends via the anchor structures; wherein

in each first spring element the first end is located opposite to the second end with respect to a center of the respective first spring element in a direction of main extension of the respective first spring element; and

the at least one coupling structure and the first spring elements act on the same side of the ring structure.

2. The angular rate sensor according to claim 1, wherein

the angular rate sensor has a plurality of coupling structures that are evenly distributed along the circumferential direction of the ring structure.

3. The angular rate sensor according to any one of the preceding claims, wherein

the electrodes for compensating for quadrature errors are in electrical interaction with portions of the coupling structures that extend substantially in a radial direction of the ring structure.

4. The angular rate sensor according to any one of the preceding claims, wherein

the coupling structures are designed as frames that are connected to the ring structure on a first side and to the substrate on a second opposite side; and

at least one portion of the electrodes which are fixed to the substrate is formed within the frames.

5. The angular rate sensor according to claim 4, wherein

the electrodes for compensating for quadrature errors are in electrical interaction with third sides of the frames, which extend substantially in a radial direction of the ring structure.

6. The angular rate sensor according to claim 5, wherein

the first and second sides of the frames are longer than the third sides of the frames.

7. The angular rate sensor according to any one of the preceding claims, wherein

the coupling structures are designed in such a way that they, together with electrodes which are fixed to the substrate, are suitable for generating the excitation oscillation and/or measuring the detection oscillation.

8. The angular rate sensor according to any one of the preceding claims, further comprising:

second spring elements which connect the coupling structures to the ring structure; wherein

the second spring elements are deformable in a radial direction of the ring structure in such a way that a radial deflection of the coupling structures leads to a greater radial deflection of the ring structure.

9. The angular rate sensor according to any one of the preceding claims, further comprising:

third spring elements which connect the coupling structures to the substrate.

10. The angular rate sensor according to any one of the preceding claims, wherein

the angular rate sensor has at least two coupling structures that are coupled to each other through a connection in such a way that their movements are coupled to each other.

11. A microelectromechanical angular rate sensor, comprising:

a flexible ring structure which forms a circle at rest and which is suitable for producing an excitation oscillation substantially parallel to the plane of the circle above a substrate, said

excitation oscillation being superimposed with a detection oscillation generated by the Coriolis force during a rotation of the ring structure; and

at least one coupling structure which is connected to the ring structure and is designed in such a way that it is, together with electrodes which are fixed to the substrate, suitable for compensating for a quadrature error of the angular rate sensor, wherein

the coupling structures are designed as frames that are connected to the ring structure on a first side and to the substrate on a second opposite side;

at least one portion of the electrodes which are fixed to the substrate is formed within the frames; and

the electrodes for compensating for quadrature errors are in electrical interaction with third sides of the frames, which extend substantially in a radial direction of the ring structure.

12. The angular rate sensor according to claim 11, wherein

the first and second sides of the frames are longer than the third sides of the frames.

13. A microelectromechanical angular rate sensor, comprising:

a flexible ring structure which forms a circle at rest and which is suitable for producing an excitation oscillation substantially parallel to the plane of the circle above a substrate, said excitation oscillation being superimposed with a detection oscillation generated by the Coriolis force during a rotation of the ring structure;

at least one coupling structure which is connected to the ring structure and is designed in such a way that it is, together with electrodes which are fixed to the substrate, suitable for compensating for a quadrature error of the angular rate sensor; and

second spring elements which connect the coupling structures to the ring structure; wherein

the second spring elements are deformable in a radial direction of the ring structure in such a way that a radial deflection of the coupling structures leads to a greater radial deflection of the ring structure.